APPENDIX A

ESP APPLICATIONS IN CEMENT INDUSTRY

BACKGROUND

The manufacture of portland cement is basically a calcining operation in which rock and earth are mixed and burned slowly in a rotating kiln. The burning drives off carbon dioxide (CO_2) and leaves a clinker product that is composed primarily of calcium silicates.[1] The basic raw materials used in portland cement manufacturing are calcium carbonate, silicon oxide, alumina, ferric oxides, and small amounts of sulfate, alkali, and carbonaceous materials.[2]

The rock and earth from the quarry are crushed, screened, and ground to the appropriate size for mixing and blending before they are fed (dry or as a slurry) into the back or feed end of the kiln. Dry process feed usually contains less than 1 percent water by weight. A typical wet process feed contains 34 to 40 percent water by weight. The electrical characteristics of the particulates generated by these two processes vary widely.

Figure A-1 is a flow diagram of the portland cement process. As shown, crushing sometimes takes place in two or three stages. Crushing, screening, and grinding operations are typically vented directly to the atmosphere and are potential sources of particulate matter emissions. The emission rate depends on the kind of raw material and its moisture content, the characteristics of the crusher, and the kind of control equipment used (usually fabric filters) and its operation and condition.

The rotary kiln is the major source of emissions at a portland cement plant. The rotary kiln has three stages of operation: feed, fuel burning and clinker cooling and handling.[3] The raw materials are fed into an elevated and inclined refractory-lined steel cylinder that rotates at approximately 60 to 90 revolutions per hour. As the kiln rotates, its slightly

inclined position causes the feed to travel slowly downward and be exposed to increasing heat. Water is evaporated from the feed with the aid of heat exchangers. As the temperature increases, organic compounds are volatilized. At about midsection of the kiln, calcium and magnesium carbonates are decomposed and CO_2 is liberated. Calcium oxide and magnesium oxide are also formed. At 2200 F, approximately 20 to 30 percent of the charge is converted to liquid. It is while the charge is in this state that the chemical reactions proceed and the material turns incandescent.

The kiln consumes large quantities of fuel and is a large source of particulate matter emissions. Design features that reduce particulate matter emissions include the use of larger kiln diameters at the feed end and the addition of suspension preheaters.

Depending on its alkali content, the dust collected in the initial stages of the kiln operation often can be returned to the kiln. This reduces disposal problems and effects a cost savings in raw material. The dust may be returned directly by mixing it with the kiln feed and introducing it in a parallel feeder. Another method of returning the dust is by insufflation; the dry dust is returned to the burning zone either through the fuel pipe or by a separate pipe running parallel to the fuel pipe.[2]

The clinker from the kiln rolls into a clinker cooler. As the clinker cooler reduces the temperature of the clinker, it recovers the heat from the clinker to preheat the primary or secondary combustion air in the kiln. After the clinker is cooled, it may be taken to a storage area or transferred to finishing mills. The finishing mills are usually rotary ball mills. Sometimes these mills are sprayed with water to keep them sufficiently cool and to minimize dehydration of the gypsum, which is added at a rate of 5 percent, to control setting times.

Although the design of the equipment used in the cement process is not complex, several design features or operating characteristics can affect the amount and quality of material found in the effluent. These include:

- Extra fine grinding in the mills seems to generate more particulate matter in the effluent.

- higher speeds of kiln rotation tend to generate more particulate matter.

The type and size of chain section used in the kiln (as a heat exchanger and to provide intimate mixing of the wet slurry and waste gases) can either increase or reduce the quantity of released dust. Short sections of dense curtain chains might help reduce dust generation, whereas loop systems might allow more to be released.

- More draft than required tends to generate more dust carryover.

- Long dry-process kilns usually contain a minimal chain section, but flue gas temperatures are usually controlled at the back end by water sprays and dilution air on the older units.

- Recently, the industry has begun to use several new types of heat exchangers (cyclone preheaters, for example) on dry-process rotary kilns; these new exchangers preheat the raw feed by intimate mixing with the waste gases.

- Insufflation (the method of returning collected material back into the kiln by blowing it into the burner flame or including it with the pulverized coal) has been processed less frequently in recent years. Although beneficial in some ways, this method has caused some difficulties in the ESP by increasing the circulation of dust concentrations and causing higher alkali content.

PROCESS VARIABLES AFFECTING ESP PERFORMANCE IN CEMENT INDUSTRY

The major application for ESP's in the cement industry is for collection of the particulate matter leaving the feed or back end of the kiln. Both wet- and dry-process rotary kilns have successfully used ESP's. Several key process variables, however, effect ESP performance. These include:

- Concentration of particulate matter in the kiln gas
- Size distribution of the waste dust
- Moisture content of kiln gases
- Gas temperature of kiln gases
- Alkali and chloride content of the particulate matter in the kiln gas.

Based on a number of field measurements of waste dust in the discharge gases of wet process kilns, the particulate emissions range from 1.5 to 6.0 gr/acf or 30 to 50 lb dust per barrel of clinker. Emissions from the dry

process will normally be 10 to 20 percent higher at similar kiln production rates.[1]

Large particles leaving the back end of the kiln are usually separated out in the dust plenum, which serves as a drop-out chamber. Thus, the material entering the ESP is finer in size than fly ash, but it exhibits a similar heterogeneous distribution.

Moisture levels in the wet process gas stream closely approximate the water percentage of the slurry in a tight system. Moisture in the dry process kiln depends primarily on the quantity of water spray conditioning used to control back-end temperatures. Moisture levels are also increased by the combustion of fuel. If the moisture level rises above 10 to 20 percent, care must be taken to maintain the ESP temperature above the dewpoint to avoid potential corrosion problems. Where precalciners are used, however, the moisture level should be approximately 4 to 5 percent to ensure adequate ESP performance.

The major effects of temperature are reflected in the modification of the electrical characteristics and the reactions of the particles as they are deposited on the plates. The electrical characteristics of almost all particulate matter collected by an ESP vary widely in the temperature range of 200° to 750°F. At the lower end of the range, electrical characteristics are affected by condensation and surface leakage; at the higher end of the range, they are affected by conductivity changes in the bulk material. The real effects at any given temperature depend on the moisture level and chemical composition of the particulate matter. The greater concern, however, is whether the ESP is operating in the critical temperature zones for effective control of the particulate matter. The most critical range for ESP cement applications is 350° to 400°. Within these critical zones, electrical readings may vary with temperature shifts as small as 10° to 15°F.

The alkali compounds (potassium and sodium), sulfur, and chloride are considered the volatile components. When the alkali material in the feed slurry is heated to approximately 1000° to 1500°F, it vaporizes and becomes entrained in the kiln combustion gases. As the gases reach the feed end of the kiln, their temperature is lower (because of the heat exchange with the chains and the heat loss resulting from water evaporation in the slurry) and

the volatile compounds condense on the feed slurry nodules. The normal movement of the slurry down the kiln returns the volatiles to the hotter area of the kiln, where they are revaporized. This vaporizing/condensing cycle continues until an equilibrium is reached between the feed alkali and the final loss from the kiln through the clinker product and the particulate in the exhausted combustion gases.

EFFECTS OF PARTICULATE CHEMISTRY ON ESP PERFORMANCE

The condensed alkali compounds appear as submicron size or fine particles, composed primarily of potassium hydroxide, potassium chloride, potassium sulfate, sodium hydroxide, sodium sulfate, and sodium chloride. The specific chemistry of the alkali compounds depends on kiln temperature, slurry chemistry, and back-end temperature. Chemical properties of typical volatile components are provided in Table A-1 and Figure A-2. The volatile compounds also condense on larger particles that are entrained by the flue gases in the drying slurry feed materials. These larger particles, which are primarily $CaCO_3$, CaO, and SiO_2, are chemically close to the composition of the feed slurry.

TABLE A-1. CHEMICAL PROPERTIES OF VOLATILE COMPONENTS OF PARTICULATES FROM CEMENT KILN PROCESSING

Compound	K		Na	
	Melting point, °C	Boiling point, °C	Melting point, °C	Boiling point, °C
Oxide	Decomp.	350	Sublim.	1275
Carbonate	894	Decomp.	850	Decomp.
Sulfate	1074	1689	884	-
Chloride	768	1411	801	1440
Hydroxide	360	1320	328	1390

The emissions from the kiln typically form a bimodal particle size distribution with a submicron size fraction and a supermicron size fraction. Although an ESP is effective in collecting both particle size fractions, the probability of collecting the larger particles is greater. The larger nonalkali particles are collected in the front fields of the ESP, whereas the

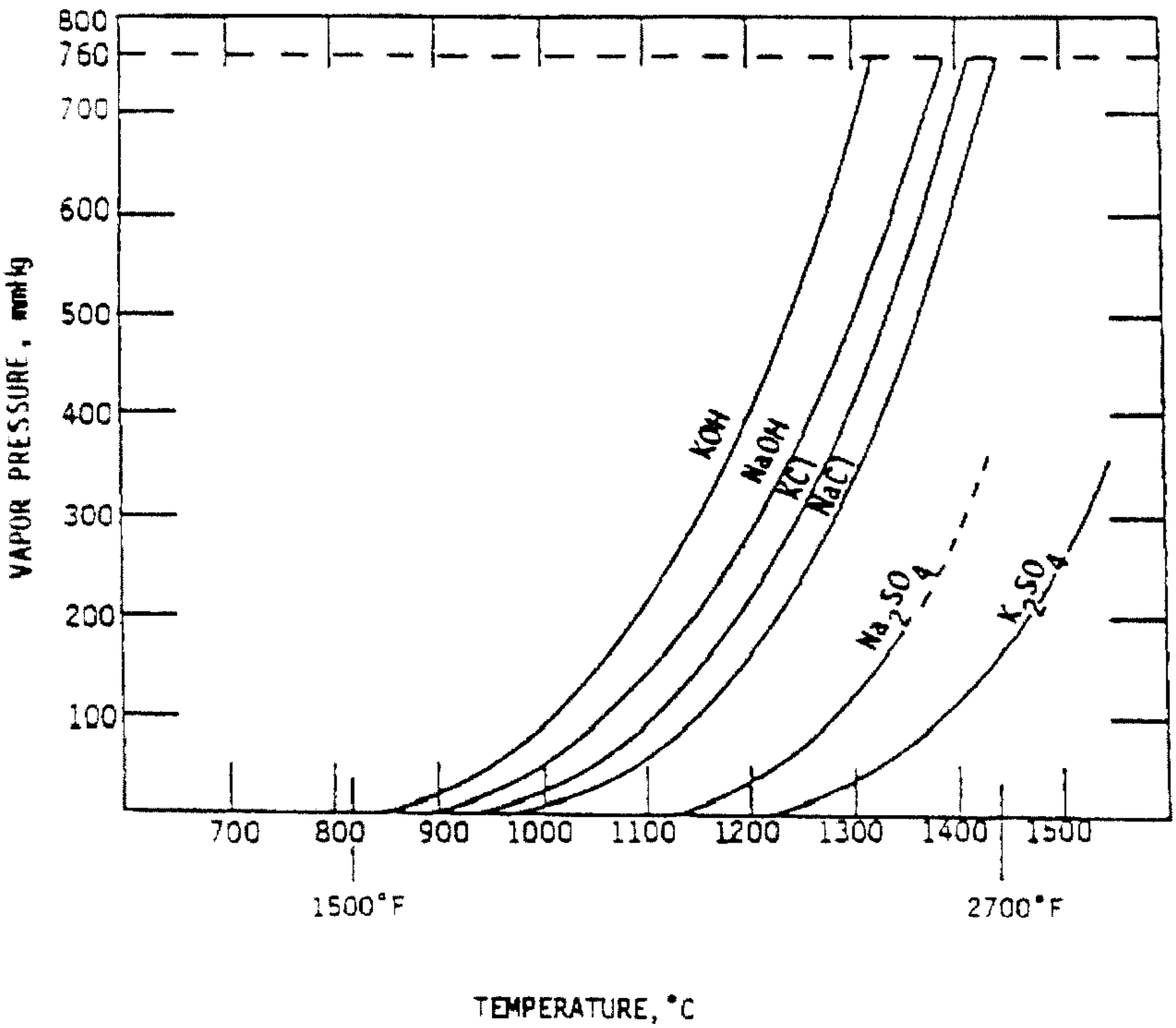

Figure A-2. Chemical properties of alkali volatile materials in cement kiln processing.

harder-to-collect finer alkali particles tend to pass through the inlet fields. A typical analysis of the dust found in ESP hoppers shows that the alkali content increases from inlet to outlet fields.

Table A-2 presents typical composition data for successive fields on a wet-process kiln ESP. Figure A-3 shows the decrease in nonalkali particulates (CaO and SiO) as a percentage of total dust composition in successive fields of a typical ESP.[4] The enrichment of alkali particulates (Na_2O, K_2O, and SO_3) results primarily from the high removal rate for nonalkali materials in the inlet field. The close association of K_2O and SO_4 is expected because a major portion of the alkali particulates is composed of potassium sulfate (Na_2SO_4). This increasing percentage is not always found, especially if most of the alkali condenses onto larger nonalkali particles. In this case, the particle size/chemistry is more homogeneous and the ESP does not segregate the dust chemically by fields.[5]

TABLE A-2. TYPICAL COMPOSITION OF DUST COLLECTED IN SUCCESSIVE FIELDS OF AN ESP SERVING A WET PROCESS CEMENT KILN (ROCK FEED)[4]

Chemical compound	Composition, %				
	Inlet	Field 1	Field 2	Field 3	Field 4
Na_2O	0.47	0.50	0.74	0.98	1.72
K_2O	5.86	7.00	12.05	19.80	35.80
Li_2O	0.34	0.24	1.00	1.64	2.16
MgO	0.41	0.85	1.09	0.20	0.12
CaO	41.98	43.26	39.41	29.09	8.19
Al_2O_3	7.98	6.15	2.14	2.15	1.75
SiO_2	13.48	12.80	11.72	8.76	3.72
Fe_2O_3	1.84	1.90	1.84	1.44	0.63
LOD	19.91	18.96	17.89	14.08	7.85
SO_3	6.84	7.19	11.15	20.31	37.03
TiO_2	0.26	0.25	0.22	0.17	0.06

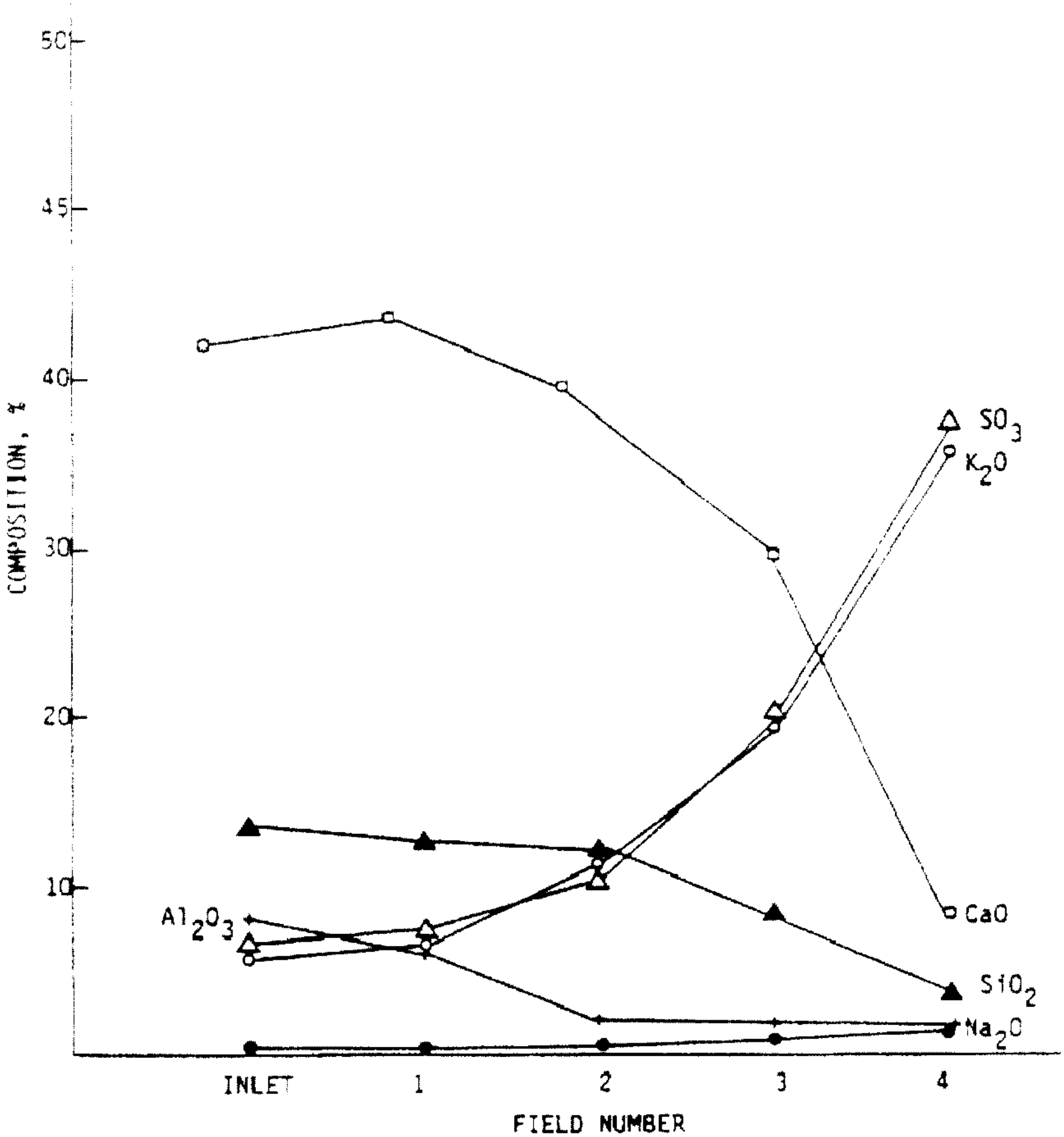

Figure A-3. Selective removal of nonalkali particulates in inlet fields of ESP and enrichment of alkali dust in outlet fields.[5]

The chemistry of the particulates also affects their resistivity. Soluble alkali components (Na_2SO_4 and NaCl) have proved to be effective in reducing resistivity.[6] Resistivity is also a function of temperature and moisture of the gas stream (Figure A-4).[7] Figures A-5 through A-9 show how cement dust resistivity changes in successive fields of a typical ESP as the alkali content increases.[8]

Process yield can be increased by returning low-alkali ESP dust to the kiln. The intent is to recover the carbonates, oxides, aluminates, and ferrous compounds. The dust may be returned by several methods: insufflation at the burner end, dry dust at the feed end, and scoops at mid-kiln. It is common practice to return the dust collected from the front ESP fields to the kiln by one of these methods.

As the alkali material in the slurry becomes vaporized, it enters the "volatile recirculation system" within the kiln. The net effect of this recirculation system is to increase the fine particle fraction of the loading to the ESP. The nonalkali materials also become suspended in the flue gases and are exhausted to the ESP. The equilibrium obtained by the combined recirculation of alkali and nonalkali dust increases the inlet loading to the ESP by a factor of 2 to 3 above that when nonrecirculation does not occur. The amount of insufflated dust that may be used is limited by the allowable alkali content in the finished cement.

KEY ESP DESIGN PARAMETERS

One key design parameter that has proved to be very useful in evaluating ESP performance is the specific collection area (SCA), which is the total collecting surface divided by the gas flow rate. Typical SCA values range from 300 to 400 ft^2/1000 acfm for wet-process ESP's,[9,10] and from 200 to 500 ft^2/1000 acfm for dry process ESP's.[10]

Since 1960, there has been a general increase in the design SCA for ESP's installed on wet-process kilns (Figure A-10). Although design SCA's for ESP's applied to dry-process kilns have also increased in general, in some situations in the late 1970's and early 1980's, the SCA was actually

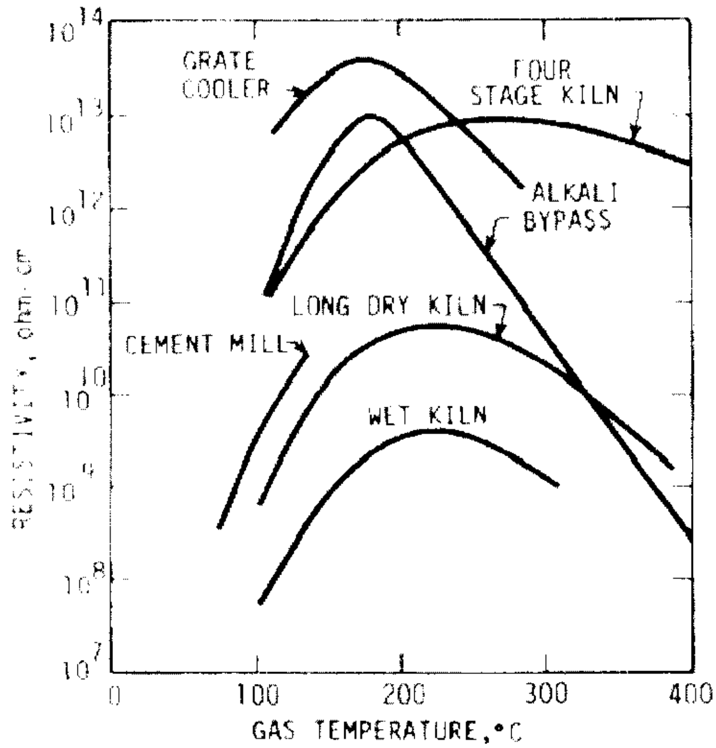

Figure A-4. Resistivity of dust from cement making processes.[7]

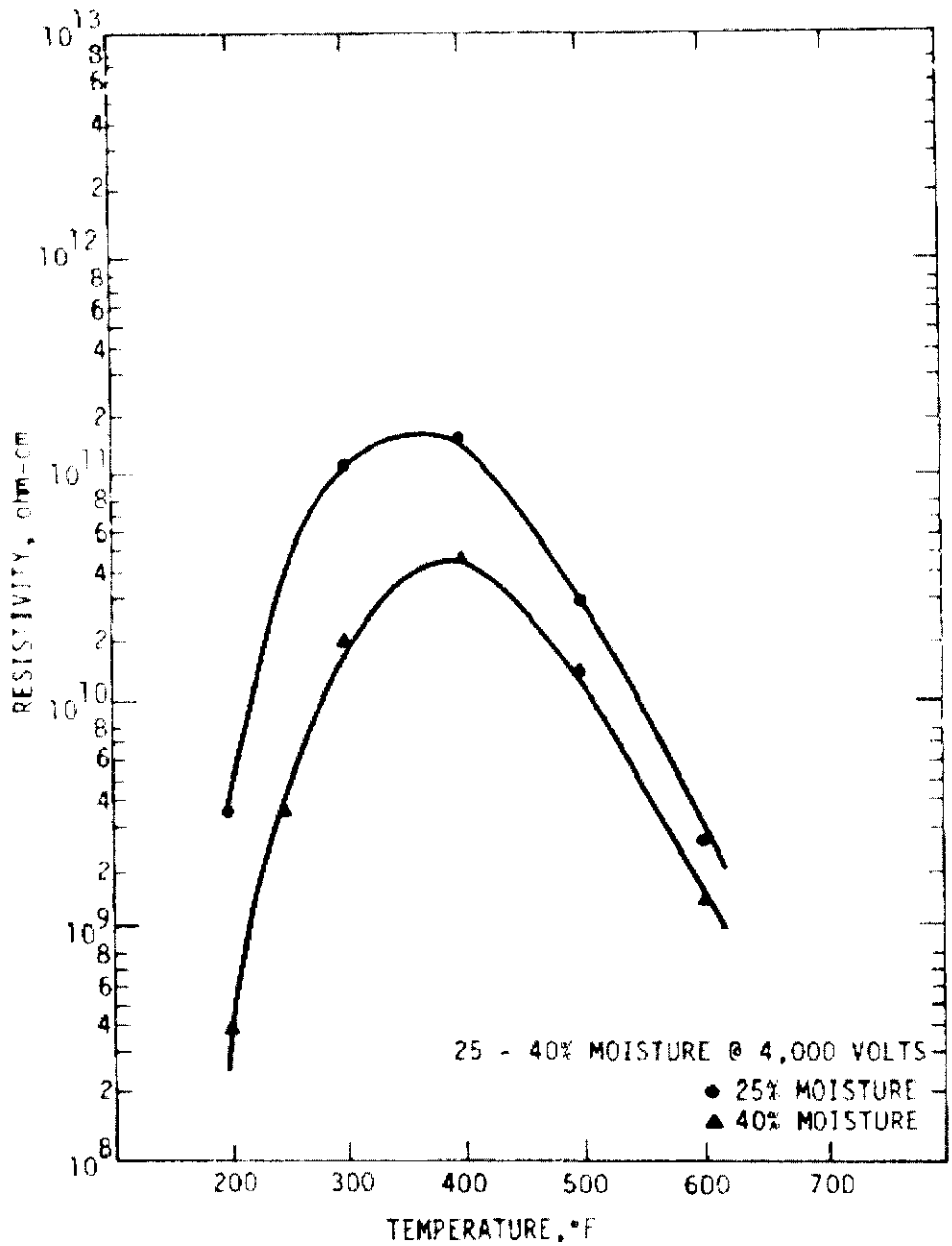

Figure A-5. Typical resistivity of cement dust collected at the inlet of an ESP serving a wet-process cement kiln (rock feed) as a function of moisture content.[5]

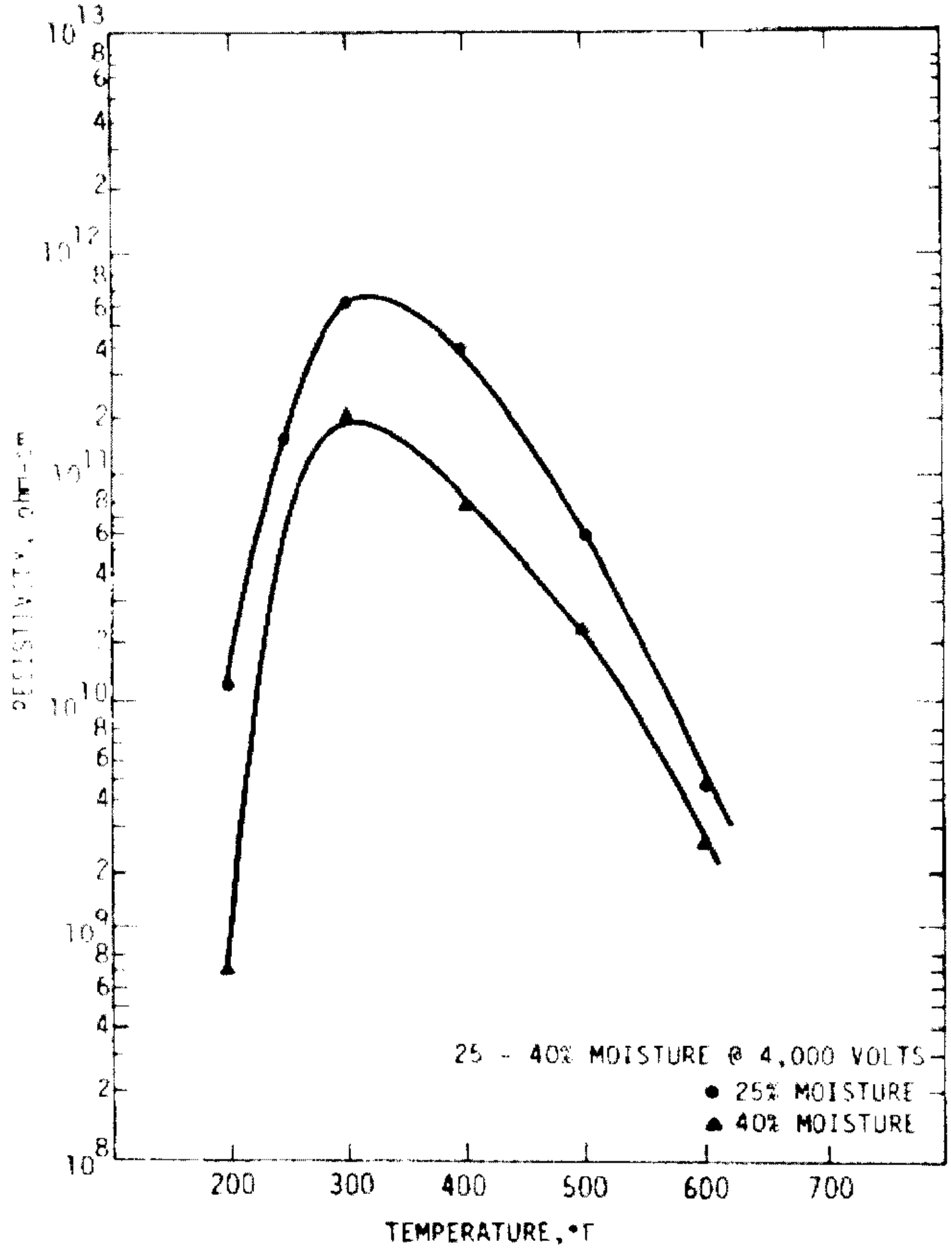

Figure A-6. Typical resistivity of cement dust collected in the first field of an ESP serving a wet-process cement kiln (rock feed) as a function of moisture content.[5]

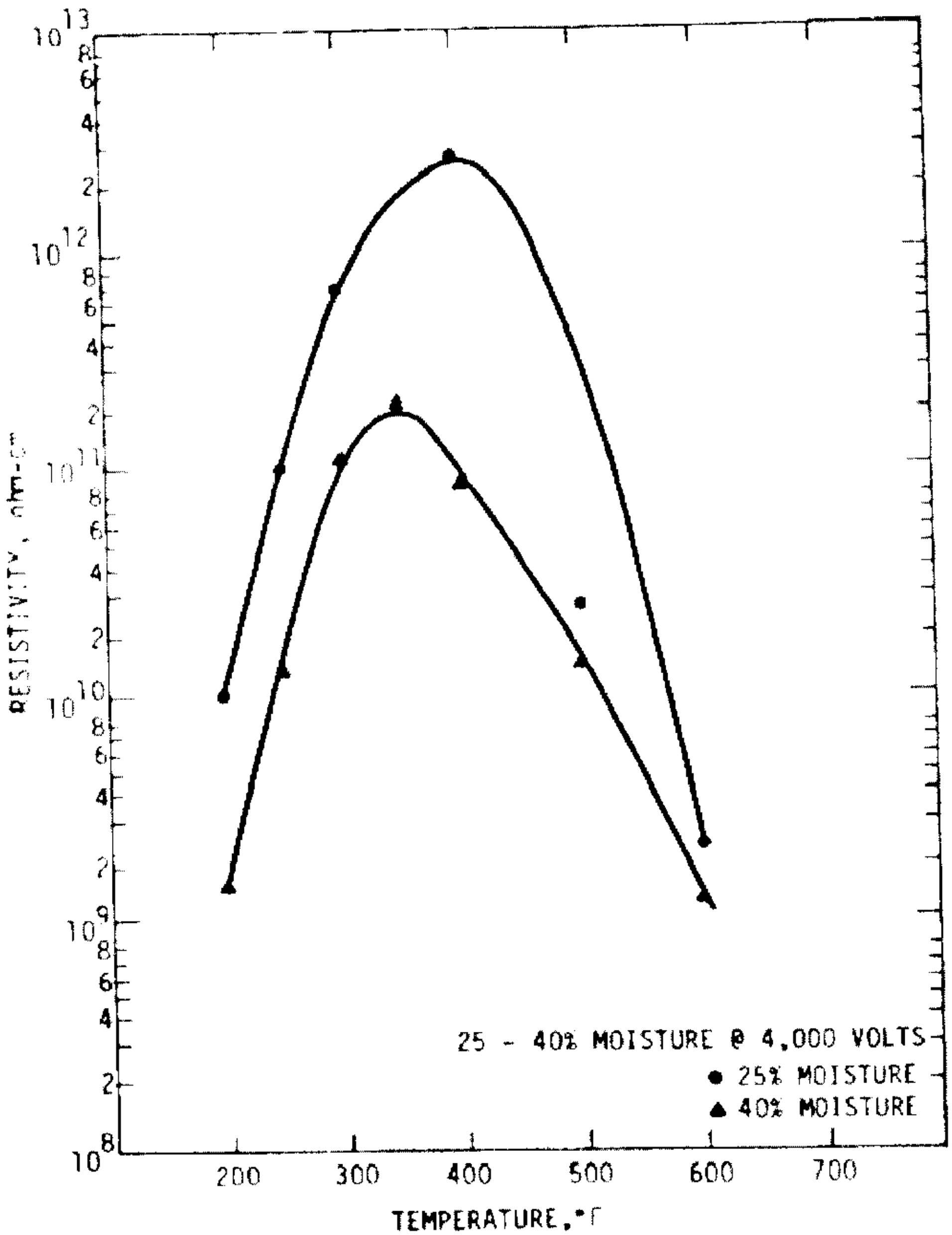

Figure A-7. Typical resistivity of cement dust collected in the second field of an ESP serving a wet-process cement kiln (rock feed) as a function of moisture content.[5]

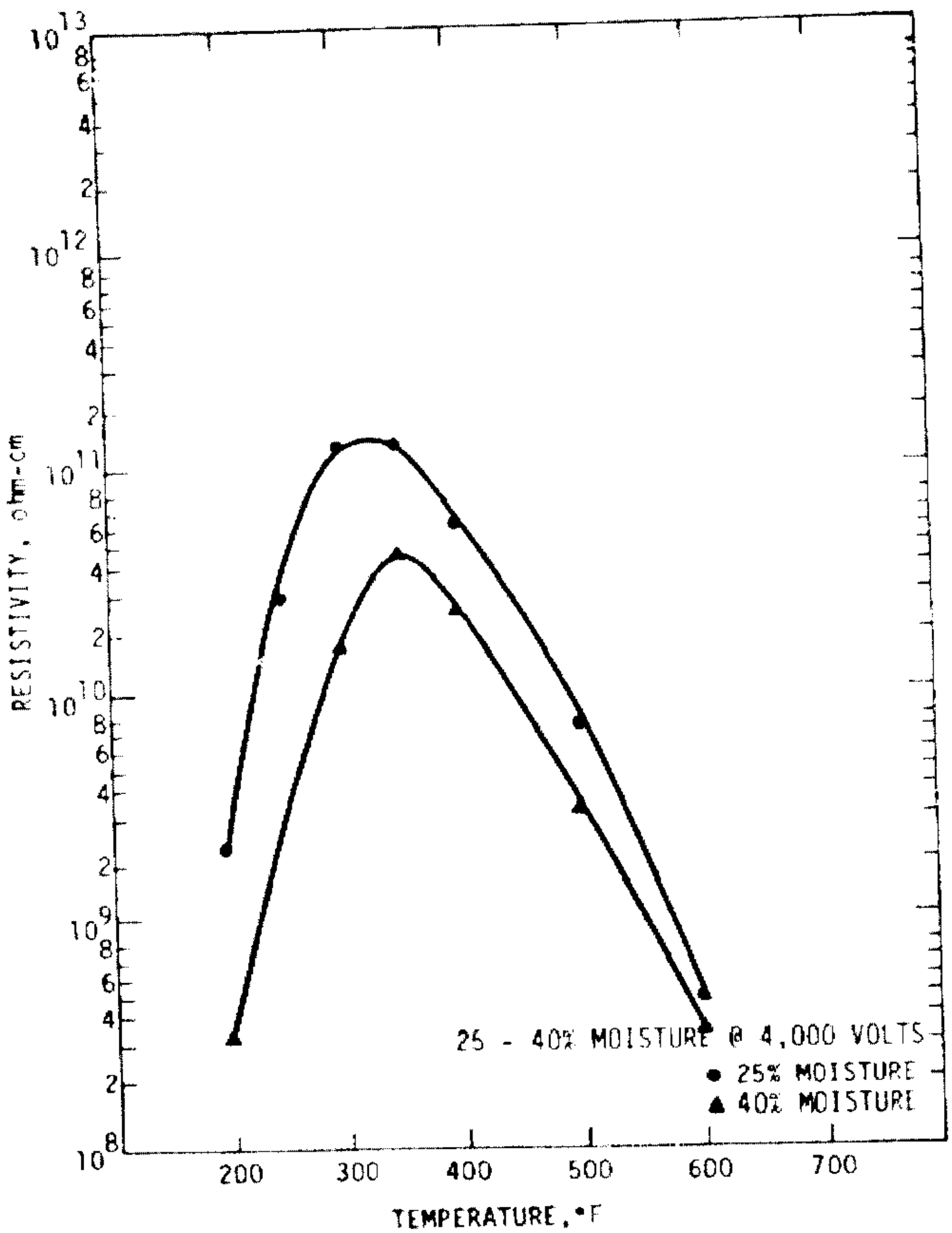

Figure A-8. Typical resistivity of cement dust collected in the third field of an ESP serving a wet-process cement kiln (rock feed) as a function of moisture content.[5]

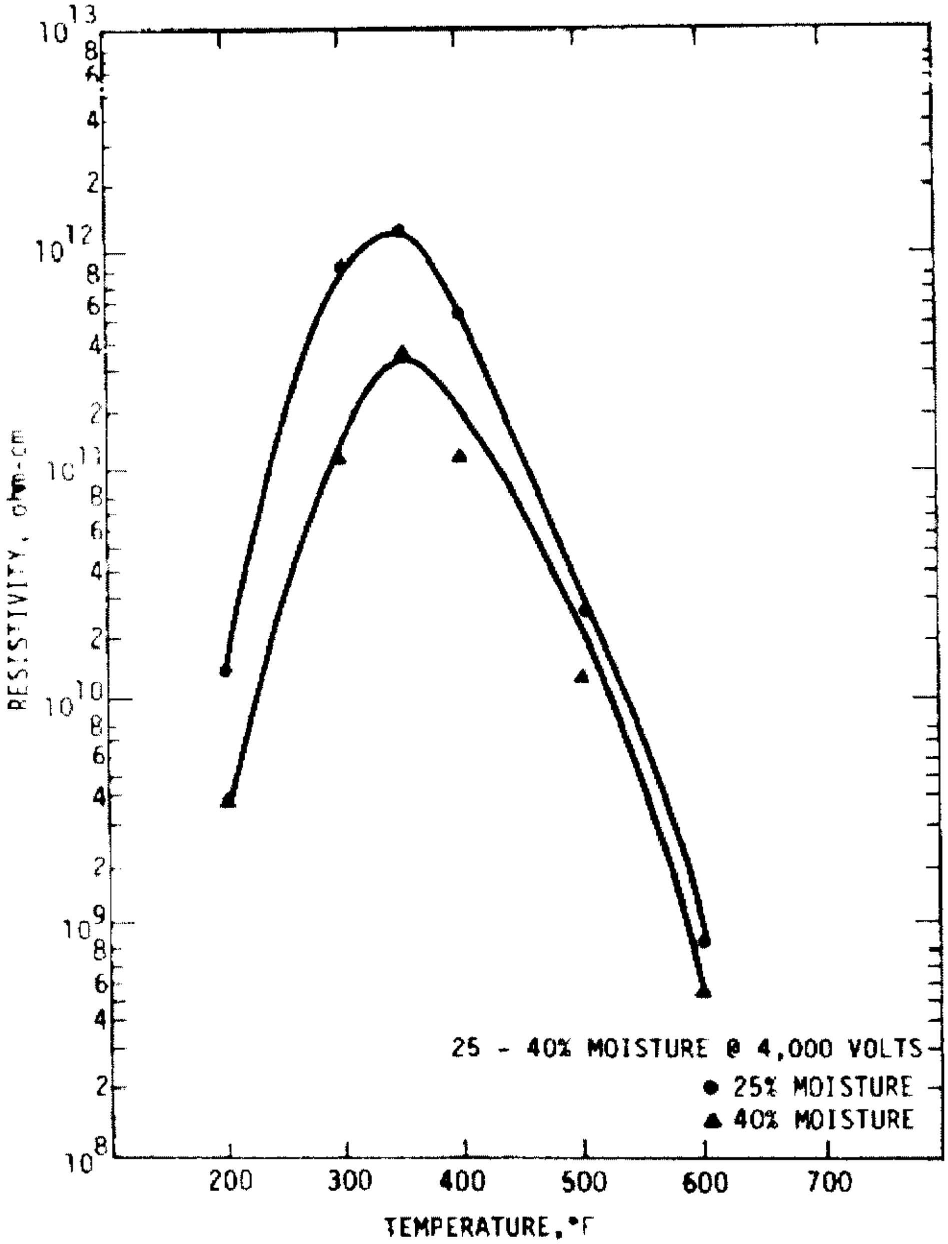

Figure A-9. Typical resistivity of cement dust collected in the fourth field of an ESP serving a wet-process cement kiln (rock feed) as a function of moisture content.[5]

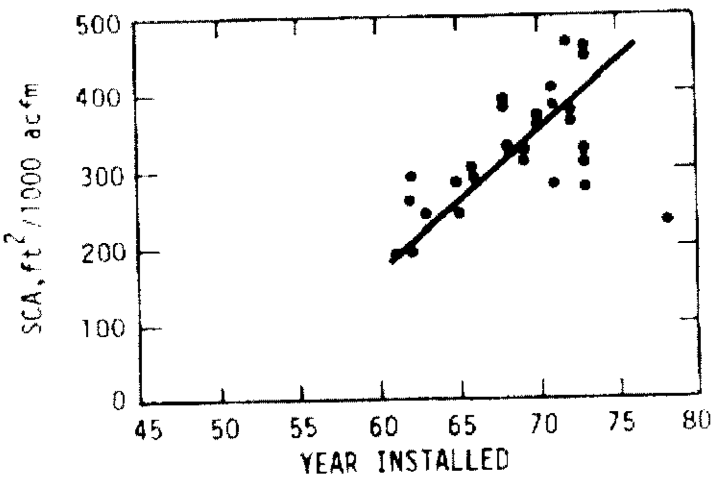

Figure A-10. Design SCA vs. year installed for wet-process kilns.

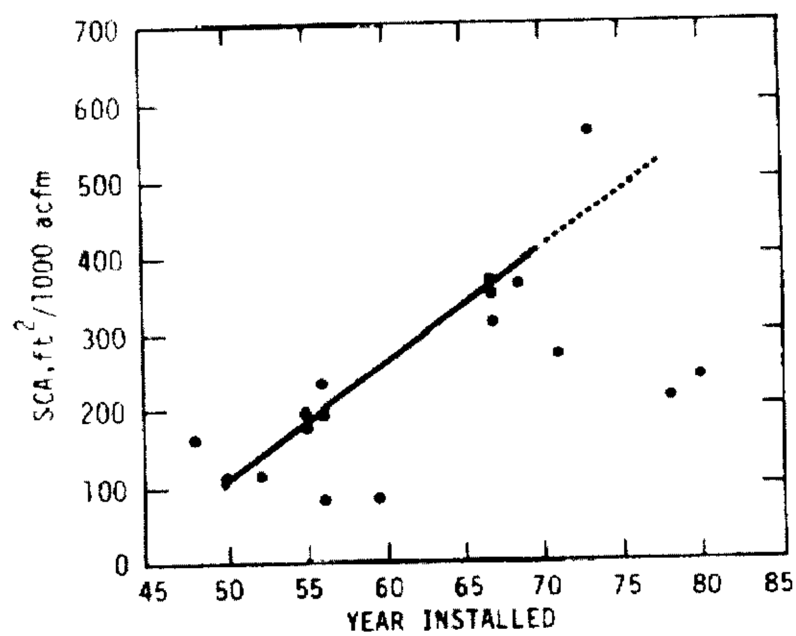

Figure A-11. Design SCA vs. year installed for dry-process kilns.

decreased (Figure A-11). The purpose of larger SCA's was to increase collection efficiency. Figures A-12 and A-13 present the design collection efficiencies versus SCA's for wet- and dry-process kilns. In general, SCA's in the range of 300 to 400 ft^3/1000 acfm are needed to achieve 99+ percent control efficiency.

OPERATING PRACTICES THAT AFFECT ESP PERFORMANCE

The grinding heat in a cement mill is almost equal to the power consumption of the mill motor. Assuming that the clinker temperature is the same as that of the finished product, all of the grinding heat has to be removed. Approximately 20 percent of this heat may be dissipated by radiation; the remaining 80 percent is usually removed by using air as the cooling medium, by evaporation of water injected into the mill, or by a combination of these methods.

If air only is used for cooling, a great amount of air is required. Because the air will be dry, electrostatic precipitation will be less effective. Injecting water into the mill for cooling and aiming at a water content in the vent air corresponding to a dewpoint of 60°C can reduce the required air volume by a factor of 5. Operating conditions for the ESP are ideal at a dewpoint of 60°C.[7].

At the startup of a cold mill, no water injection is possible until the cement temperature has risen above 110°C. During this time, ESP performance is often less than ideal because the dewpoint of the air from the mill is too low. When this lower efficiency is not acceptable, a special method can be used that automatically keeps the dust loss low during the startup period. The method involves reducing the air flow through the mill by approximately 40 percent during the period with no water injection. The principles of this method are as follows:[7]

- The ESP is energized before the fan and mill are started; this suppresses initial dust puffs.

- When the fan is started, the air flow through the mill is reduced to the minimum required to keep the mill inlet dust-free. This reduces the air velocity in the mill and ESP and lowers the dust concentration.

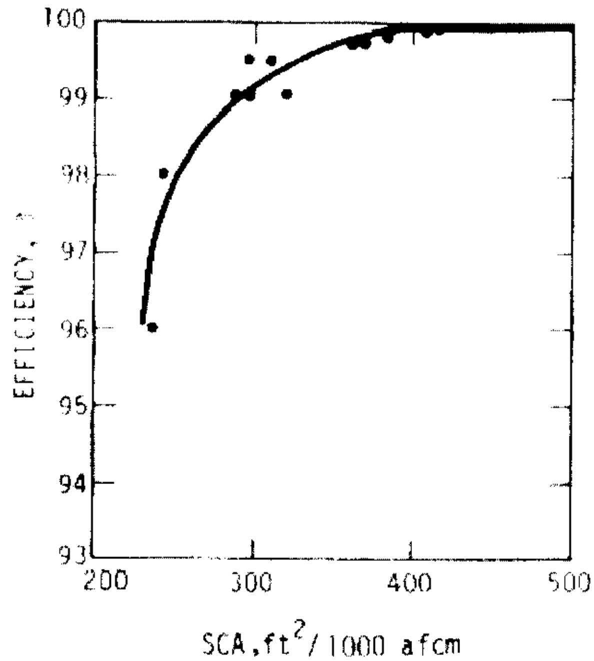

Figure A-12. Design collection efficiency vs. SCA for wet process kilns.

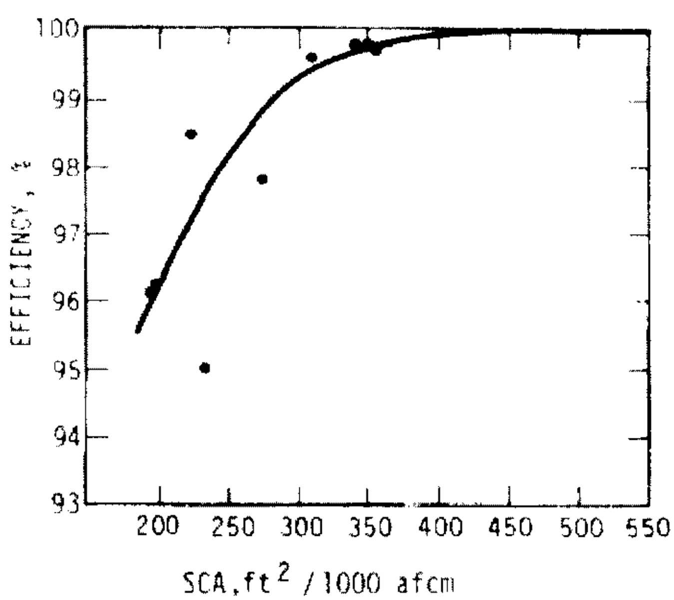

Figure A-13. Design collection efficiency vs. SCA for dry process kilns.

- Startup of the ESP rapping gears is delayed to avoid dust puffs during periods of difficult operating conditions (when dewpoint is low). After a few minutes of operation, the dewpoint rises as a result of evaporation of water from the gypsum and the rapping can begin.

- When the water injection starts, the air flow through the mill is immediately regulated up to a level corresponding to the desired dewpoint for normal cement mill operation, i.e., 60°C.

- An automatic spark rate controller on the high-temperature rectifiers keeps the ESP voltage at optimum level during the varying operating conditions.

- The ESP remains energized and the rapping gears continue to operate for a certain period after the cement mill is stopped; this cleans the air drawn through the system by natural draft.

Figure A-14 shows results from tests run out at a Danish cement plant that used the method just described. Because dust emissions remain low during the startup period in spite of the reduced dewpoint, ESP migration velocity is reduced, primarily because of the reduced air flow through the ESP and the low inlet dust concentration.

Because the resistivity of the dust after a cyclone preheater kiln is usually quite high, a very large ESP is required if the gases are to be treated without water conditioning. Therefore, water conditioning is the rule because it reduces the gas volume, reduces the resistivity of the dust, and increases the dielectric strength of the gas. For these reasons, water conditioning has a very pronounced, positive effect on ESP performance. This is directly reflected in the operating voltage, as illustrated in Figures A-15 and A-16.

Figures A-15 and A-16 show the effect of water conditioning on ESP current-voltage characteristics for a preheater kiln with a conditioning tower and for a preheater kiln with a raw mill. As the water conditioning increases and the gas cools, the ESP voltage rises dramatically and performance improves. Over a wide temperature range, the current-voltage characteristics are almost vertical, or even curve back, which indicates "back-corona" due to high resistivity.[7]

Figure A-17 shows a preheater kiln with a conditioning tower and a raw mill installed in parallel. In this example, the major part of the hot kiln

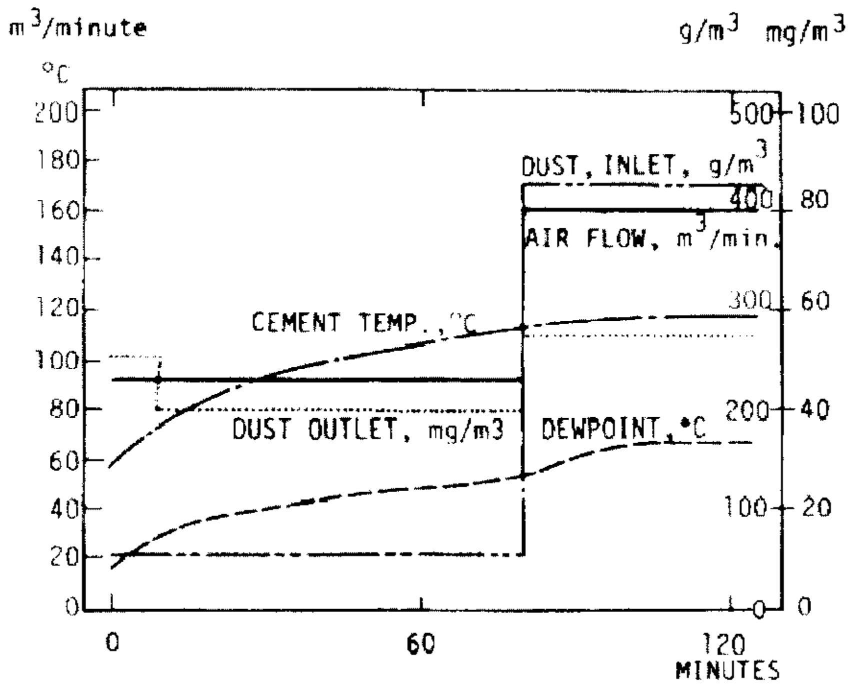

Figure A-14. Automatic control of operating conditions during startup of cement mill.[7]

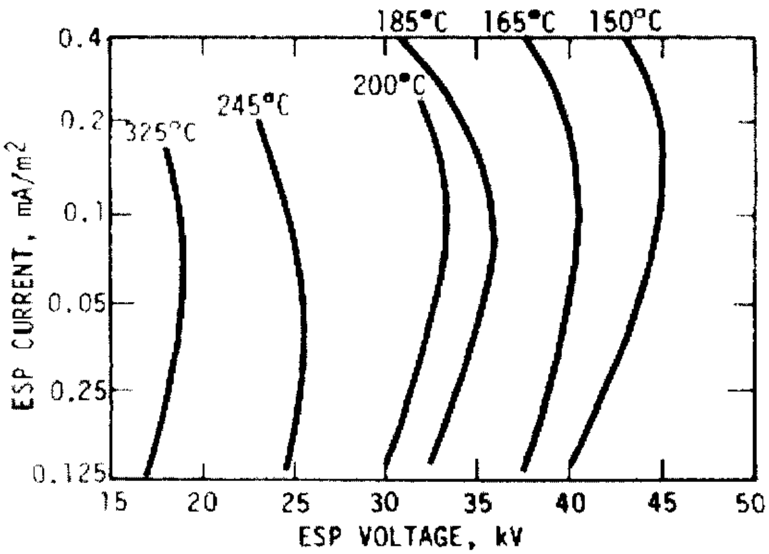

Figure A-15. ESP current-voltage characteristics with varying H_2O conditioning of gas from cyclone preheater kiln with a conditioning tower.[7]

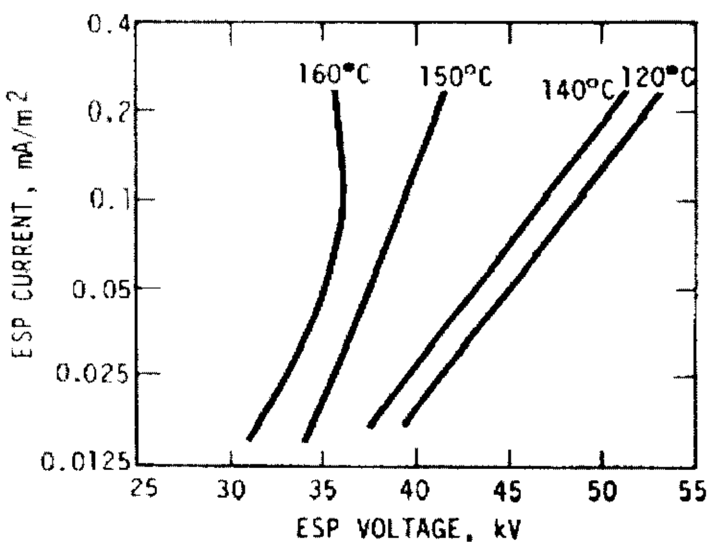

Figure A-16. ESP current-voltage characteristics with varying H_2O conditioning of gas from cyclone preheater kiln with raw mill.[7]

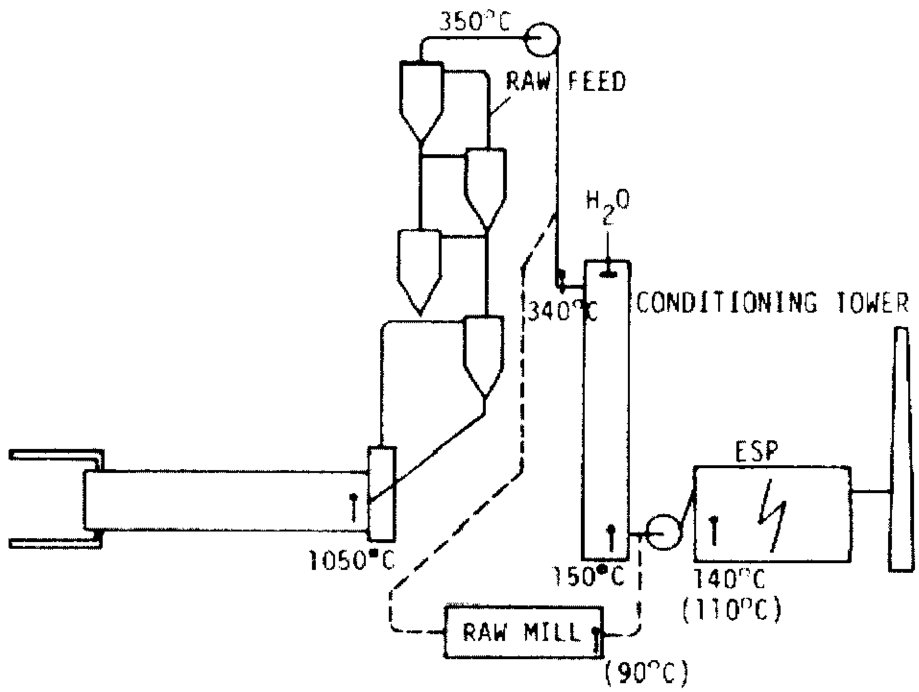

Figure A-17. Cyclone preheater kiln with conditioning tower and raw mill.[7]

gas is drawn through the raw mill, where the gas obtains moisture from the raw materials. The cooled gas from the raw mill is mixed with the remaining part of the kiln gas, which has been cooled in the conditioning tower, and the gas mixture enters the ESP with an ideal operating temperature and moisture. When the raw mill is stopped, all the kiln gases pass through the conditioning tower, where they are cooled, and acceptable ESP performance is obtained. Thus, good ESP performance can be maintained with the mill in operation or with the mill stopped.

Unstable ESP operation and considerably reduced efficiency can occur, however, in the transition phases between the two modes of operation, especially in connection with startup of the raw mill. When the mill is started, the major part of the gas is diverted from the conditioning tower to the mill. Because the amount of water injected and evaporated in the conditioning tower is controlled by the gas temperature at the tower outlet, it is reduced in proportion to the reduction in gas flow through the tower. This reduction might be accompanied by a minor or perhaps even a major fluctuation of the gas temperature at the tower outlet, depending on the properties of the conditioning tower's automatic regulation equipment. The hot gases drawn through a cold mill must heat the mill and the raw materials before full-level evaporation of water from the mill is reached. The result is a temporary humidity deficiency in the gas stream from the mill, which, when combined with possible fluctuations of the temperature of the gas stream from the conditioning tower, might result in serious deterioration of the ESP performance during and after the changeover phase.[7]

One method that has been used to overcome this problem is to increase the water injection in the conditioning tower while the mill is heating up. This can be accomplished by an automatic, temporary displacement of the set point of the temperature regulator controlling the water injection. For example, the displacement might be of the magnitude -25°C. This method presupposes that the conditoning tower has sufficient cooling capacity to avoid the sludge formation that would normally accompany such a temperature lowering. Another method is to preheat the raw mill by drawing a small hot gas stream through the mill before the startup.[7] A third method involves the use of automatic control and synchronization of damper movement, water injection

changes, and mill startup. This method was successfully introduced at a Greek cement plant where increased dust emissions during changeover periods was a problem. Figure A-18 illustrates the results obtained in this case.

The dust from a grate cooler usually has a high resistivity, and the excess air has a low moisture content; nevertheless, the fairly large particle size of the dust makes it easily precipitable, especially if the ESP performance has been improved and stabilized by increasing the moisture content of the excess air. A few percent moisture by volume is sufficient, and such small quantities of water can be injected without difficulty and evaporated in the grate cooler above the grate at the cool end of the clinker bed.[7]

Occasionally, however, a grate cooler may be subject to large operational variations. Rings may form in the kiln and dam up the mix, and when the ring breaks down, excessive quantities of materials flush through the burning zone and enter the grate cooler. When this occurs, the temperature of the excess air may rise to 400° to 425°C.

Compliance with emission standards during periods of temporary unstable cooler operation requires the control of ESP operating conditions. Planning an appropriate control strategy requires detailed quantitative knowledge of the interactions between the operating parameters (gas temperature, moisture content and resistivity) and ESP performance. Figure A-19 illustrates the relationship between resistivity and air temperature and moisture content, whereas Figure A-20 shows the relationship between ESP migration velocity and resistivity.

In Figure A-21, these two relationships have been combined, and the effect of air temperature and moisture content on the migration velocity through the ESP voltage (independent of the resistivity) has been included. Thus, this figure shows the direct relationship between migration velocity and air temperature and moisture content and also the effects of resistivity as the dielectric strength of air effects. The two dashed lines in the diagram indicate the winter and summer limits for ambient air moisture content, and the hatched area represents possible variations in ESP operating conditions without water conditioning, assuming excess air temperature variations from 90°C to 400°C. It should be noted that an area of low migration velocity occurs around 180°C.[7]

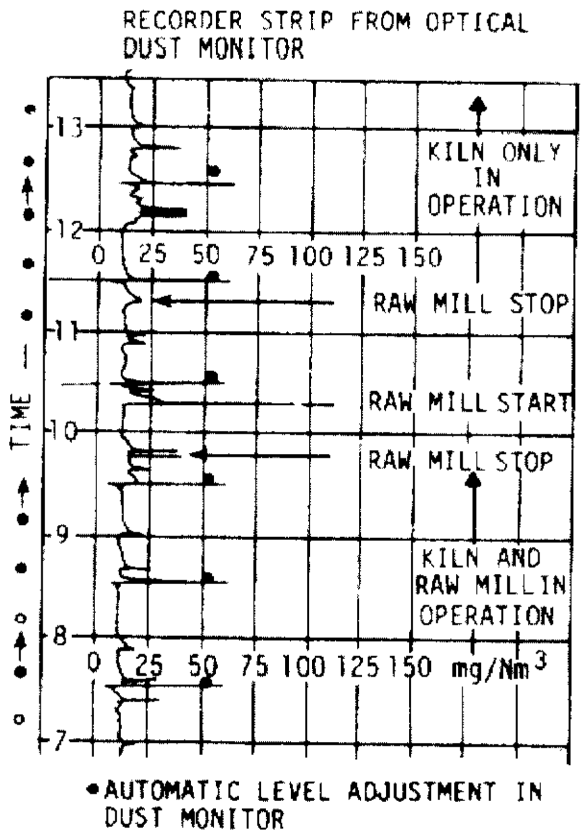

Figure A-18. Dust emissions at a Greek cement plant that used automatic control and sychronization of damper movement, water injection changes, and mill startup to overcome problems during changeovers.[7]

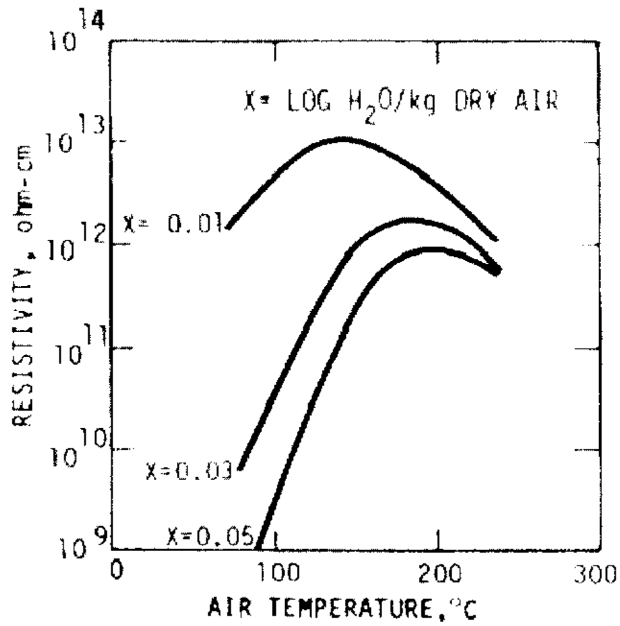

Figure A-19. Resistivity vs. air temperature and moisture content.[7]

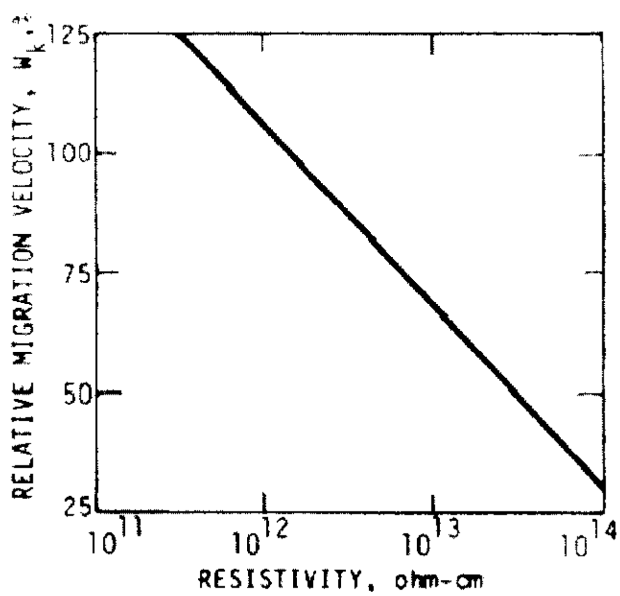

Figure A-20. Precipitator migration velocity vs. resistivity.[7]

Water conditioning of the excess air by injection and evaporation of water in the cooler can change the ESP operating conditions, for example, from point A in Figure A-21 to point B, along the line A-B. The slope of the line A-B is determined by the proportion between the air cooling effect and the air humidifying effect of the injected water. Any other conditioning line (for example, A1-B1) will therefore have practically the same slope in the diagram as A-B. The length of a conditioning line is directly proportional to the amount of water injected. These assertions, of course, are only true if the water is injected into the cooler in such a way that it evaporates in and cools the excess air, not the clinker.[7]

The information in Figure A-21 indicates that an appropriate control system should be designed to maintain ESP operating conditions in areas with high migration velocities, i.e., outside or close to the ω_3 curve and avoiding the low ω area of dry air around 180°C.

With sets of water injection nozzles arranged above the cool end of the clinker bed and controlled by the cooler exit air temperature, ESP operating conditions can be maintained approximately along the operating control line I-II (Figure A-21). This method will provide satisfactory ESP efficiency and acceptable dust emission levels during varying clinker cooler operation.[7]

STARTUP AND SHUTDOWN PROCEDURES

As noted, periods of process startup and shutdown are critical to ESP operation. The following items are provided as general operating rules of thumb to follow during these periods[11]:

- If hopper or support insulator heater elements are available, these heat sources must be in operation at least 3 hours before startup.
- The combustible level in the gas exiting the kiln should be ascertained before the ESP is electrically energized.
- It is generally preferable to preheat the ESP to as high a temperature as possible before energization of the power supplies. Gas temperatures of 180° to 200°F at the exit of the ESP are recommended. If ESP operation is required before this temperature range is reached, the outlet electrical fields should be energized first at low power settings.

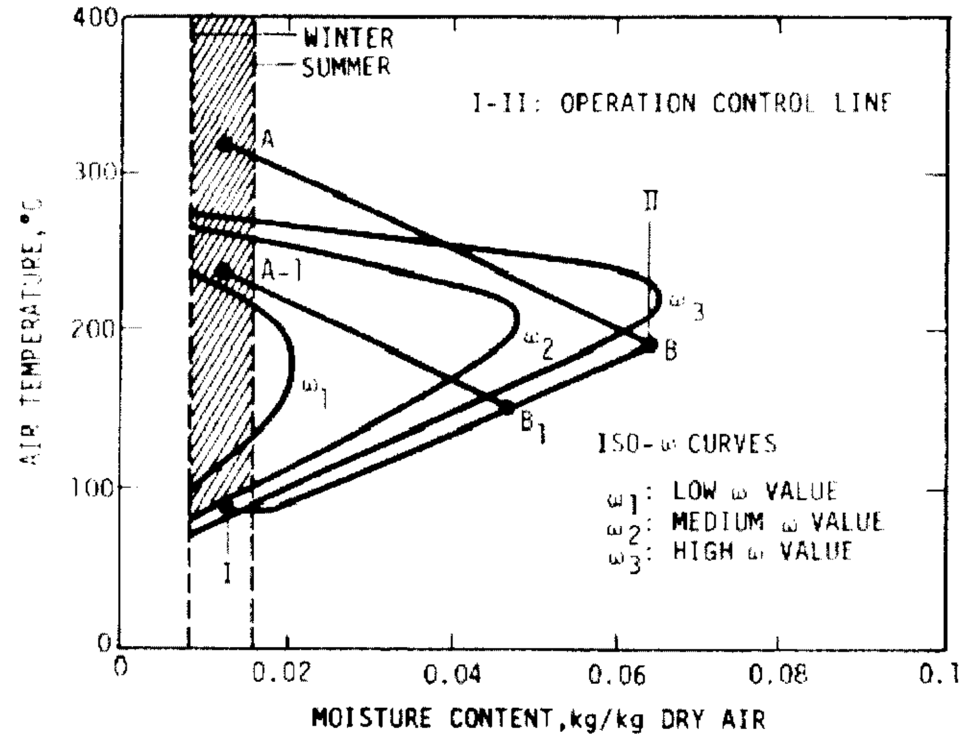

Figure A-21. Relationship between migration velocity ω and air temperature and moisture content including resistivity effect.[7]

- All rapper equipment should be placed in service prior to startup of kiln.
- All hopper evacuation equipment must be in operation before startup of the kiln.
- Upon shutdown of the process, the electrical sections of ESP should be deenergized before the gas temperature falls below 200° to 250°F at the exit of ESP. Shutdowns of the ESP should be initiated in an orderly fashion from the inlet to outlet fields. Rapper operation must be kept at maximum intensity. The time intervals for shutdown of the power supplies should be gauged to minimize the discharge from stack. Each installation may require a different procedure, but the object is to achieve effective cleaning of the electrode surfaces. The operation of the induced draft fan must be considered in the procedure. All conveyors and hopper systems should be kept operable.

Effective operation of an ESP in a cement plant depends on proper design and proper maintenance. Table A-3 presents some of the more common problems associated with ESP operation. As indicated, most malfunctions result from lack of maintenance and attention to the control system.[2]

TABLE A-3. DETECTION AND SOLUTION OF ESP OPERATING PROBLEMS[2]

Control panel indicators			ESP conditions/ panel indications	ESP control efficiency[a]	Possible problem	Problem solution
Primary voltage, a.c.	Primary current, amps	Secondary current, mA				
350[b]	40[b]	160[b]	Normal operation	Normal		
285	120	500	Gas volume and dust load decreases.	Higher than normal		
400	30	140	Dust load increases.	Usually higher than normal		
350-400	40-150	100-700	In wet processes, temperature increases but resistivity is constant. In dry processes, temperature and resistivity increase.	Higher than normal for wet processes, but lower than normal for dry processes		
240	40	200	Gas temperature decreases.	Normal unless below dewpoint		Raise process temperature.
240	170	400	Arcing between electrodes	Less than normal	Higher hopper level Dust bridging in in hopper	Increase dust removal rate. Use hopper vibrator.
400	40	160	Added primary voltage is required to maintain constant current; spark rate increases.	Less than normal	Failure of discharge electrode rapper to remove dust from electrodes.	Increase rapping intensity. Repair rapper system.
240	40[b]	160	Less primary voltage is required to maintain constant current. Spark rate increases.	Less then normal	Failure of rapper on collection plate to remove dust buildup	Increase rapping intensity. Repair rapper system.

TABLE A-3 (continued)

Control panel indicators						
Primary voltage, a.c.	Primary current, amps	Secondary current, mA	ESP conditions/ panel indications	ESP control efficiency[a]	Possible problem	Problem solution
0-350	0-40	0-160	Violent fluctuation of indicators; high arcing noise	Zero to normal	Broken electrode with top part swinging back and forth	Isolate section until electrode can be replaced.
0	120	0	No current flow to precipitator	Zero	Electrical short circuit of transformer-rectifier (T-R) set, or wire grounded out	Repair or replace T-R set.
			High spark rate	Less than normal	Air leakage through inlet ductwork Air leakage through inspection hatches	Seal points of of leakage. Seal hatch doors.
			Corrosion (internal inspection)	No immediate effect	Inlet gas at temperatures less than dewpoint Problems encountered during startup and shutdown of kiln	Maintain gas temperature above dewpoint. Use insulation and hopper heaters.

[a]The effects of ESP problems can only be stated on a qualitative basis.

[b]Multiple-field ESP: primary voltage decreases in moving from inlet to outlet fields, and primary current increases in moving from inlet to outlet fields.

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10. The McIlvaine Co. The Electrostatic Precipitator Manual. Northbrook, Illinois. December 1976.

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Attachment #4

Summary of Average Hourly Opacity > 20%

Form B, Excess Opacity Report for Third Quarter 2003

1	Kiln start up	Start Up
2	Kiln shut down	Shut Down
3	Raw mill start up	Start Up
4	Raw mill shut down	Shut Down
5	Opacity increased while starting up auxiliary equipment	Start Up
6	Erratic feed rate	Malfunction
7	Erratic fuel rate	Malfunction
8	Plugged system	Malfunction
9	Broken dust collector bag(s)	Malfunction
10	Electrical malfunction in precipitator	Malfunction
11	Mechanical malfunction in precipitator	Malfunction
12	Lost auxiliary equipment	Shut Down
13	Lost spray tower exit temperature control	Malfunction
14	Working in/on process system	Startup/Shutdown
15	Working in/on Pollution Control Equipment	Startup/Shutdown
16	Fan output began ramping up or down	Malfunction
17	Process/ID Fan malfunctioned or shut down unexpectedly	Malfunction
18	Malfunction of sprays at spray tower	Malfunction
19	Process gas temperature was out of optimum range	Malfunction
20	Electrical surge / outage / power bump	Malfunction
21	Unknown cause	Unknown or Permitted Cause
22	Dirty monitor lens	Malfunction
23	Monitor failed or began sending erroneous data	Malfunction
24	Other cause	Unknown or Permitted Cause
25	WEDQ/ADQ Approved Precipitator Inlet Temperature Test	Unknown or Permitted Cause

A	Startup, shutdown, or slowing down of the process	Startup/Shutdown
B	Control equipment not functioning properly	Malfunction
C	Problem with process	Malfunction
D	Routine maintenance or other known problem	Malfunction
E	Unexplained cause	Unknown or Permitted Cause

Startup/Shutdown:

1	Kiln start up
3	Raw mill start up
5	Opacity increased while starting up auxiliary equipment
2	Kiln Shut down
4	Raw mill shut down
12	Lost auxiliary equipment
14	Working in/on process system
15	Working in/on Pollution Control Equipment
A	Startup, shutdown, or slowing down of the process

Malfunction of the Process Equipment:

6	Erratic feed rate
7	Erratic fuel rate
8	Plugged system
9	Broken dust collector bag(s)
10	Electrical malfunction in precipitator
11	Mechanical malfunction in precipitator
13	Lost spray tower exit temperature control
16	Fan output began ramping up or down
17	Process/ID Fan malfunctioned or shut down unexpectedly
18	Malfunction of sprays at spray tower
19	Process gas temperature was out of optimum range
20	Electrical surge/outage/power bump
22	Dirty Monitor Lens
23	Monitor failed or began sending erroneous data
B	Control equipment problems
C	Problem with process
D	Routine maintenance or other known problem

Unknown or Permitted Causes:

21	Unknown cause
24	Other cause
E	Unexplained cause

Mountain Cement Company
Average Opacity [illegible]
Kiln [illegible]

Date	Begin Time	End Time	Duration HH:MM	Duration Hours	Cause	Category
Fourth Quarter, 2004						
10/26/04	19:06	20:06	1:00	1.00	Raw Mill Shut Down	Startup/Shutdown
12/17/04	22:36	23:42	1:06	1.10	Lost Auxiliary Equipment	Startup/Shutdown
12/28/04	13:00	14:24	1:24	1.40	Lost Auxiliary Equipment	Startup/Shutdown
Total				**3.50**		
Third Quarter, 2004						
7/14/04	9:42	11:54	2:12	2.20	Malfunction of sprays at spray tower	Malfunction
7/19/04	15:42	16:54	1:12	1.20	Electrical surge/outage/power bump	Malfunction
9/2/04	10:42	14:12	3:30	3.50	Working in/on Pollution Control Equipment	Startup/Shutdown
9/12/04	18:06	19:06	1:00	1.00		Malfunction
Total				**7.90**		
Second Quarter, 2004						
6/3/04	12:06	13:18	1:12	1.20	Working in/on process system	Startup/Shutdown
Total				**1.20**		
First Quarter, 2004						
2/2/04	9:42	17:12	7:30	7.50	Process/ID Fan Malfunctioned or Shut Down	Malfunction
2/2/04	20:30	21:36	1:06	1.10	Process/ID Fan Malfunctioned or Shut Down	Malfunction
2/10/04	3:42	6:48	3:06	3.10	Lost auxiliary equipment	Startup/Shutdown
2/12/04	4:54	8:42	3:48	3.80	Plugged System	Malfunction
2/12/04	8:48	10:00	1:12	1.20	Plugged System	Malfunction
2/12/04	13:12	14:18	1:06	1.10	Plugged System	Malfunction
2/12/04	22:42	:36	1:54	1.90	Plugged System	Malfunction
2/13/04	2:00	4:24	2:24	2.40	Plugged System	Malfunction
Total				**22.10**		
Fourth Quarter, 2003						
10/20/04	14:42	15:54	1:12	1.20	Working in/on pollution control equipment	Startup/Shutdown
11/11/03	5:00	7:48	2:48	2.80	Working in/on pollution control equipment	Startup/Shutdown
11/13/03	13:36	16:48	3:12	3.20	Working in/on pollution control equipment	Startup/Shutdown
11/19/03	10:06	17:12	7:06	7.10	Plugged System	Malfunction
12/3/03	16:24	17:30	1:06	1.10	Electrical Surge/outage/power bump	Malfunction
Total				**15.40**		
Third Quarter, 2003						
7/11/03	9:06	10:42	1:36	1.60	Test	Unknown/excused
7/31/03	16:06	17:48	1:42	1.70	Plugged System	Malfunction
8/5/03	15:42	17:42	2:00	2.00	Working in/on process system	Startup/Shutdown
9/3/03	15:24	17:42	2:18	2.30	Opacity Increased while starting up auxiliary equipment	Startup/Shutdown
9/18/03	17:24	22:54	5:30	5.50	Working in/on pollution control equipment	Startup/Shutdown
Total				**13.10**		

MCC Detail of Causes of hours of average opacity above 20 percent

Second Quarter, 2003						
4/26/03	19:54	21:00	1:06	1.10	Process gas temperature was out of optimum range	Malfunction
5/27/03	23:42	2:54	3:12	3.20	Lost spray tower exit temperature control	Malfunction
6/7/03	5:48	7:18	1:30	1.50	Electrical surge/outage/power bump	Malfunction
6/16/03	17:00	18:54	1:54	1.90	Lost auxiliary equipment	Startup/Shutdown
6/16/03	20:00	22:48	2:48	2.80	Lost auxiliary equipment	Startup/Shutdown
Total				**10.50**		
First Quarter, 2003						
1/1/03	8:24	9:42	1:18	1.30	Lost spray tower exit temperature control	Malfunction
1/1/03	13:00	15:00	2:00	2.00	Lost spray tower exit temperature control	Malfunction
1/1/03	16:18	19:54	3:36	3.60	Lost spray tower exit temperature control	Malfunction
1/2/03	13:54	15:12	1:18	1.30	Lost spray tower exit temperature control	Malfunction
1/2/03	15:18	18:18	3:00	3.00	Lost spray tower exit temperature control	Malfunction
1/20/03	4:54	6:18	1:24	1.40	Lost spray tower exit temperature control	Malfunction
1/27/03	16:12	17:18	1:06	1.10	Process Gas Temperature was out of range	Malfunction
2/5/03	17:06	4:30	10:36	10.60	Working in/on process system	Startup/Shutdown
3/16/03	18:36	21:30	2:54	2.90	Electrical Surge/outage/power bump	Malfunction
Total				**27.20**		
Fourth Quarter, 2002						
10/8/02	10:24	11:54	1:30	1.50	Opacity increased while starting up auxiliary equipment	Startup/Shutdown
10/10/02	10:48	12:24	1:36	1.60	Working in/on process system	Startup/Shutdown
10/25/02	8:06	10:36	2:30	2.50	Working in/on process system	Startup/Shutdown
12/3/02	8:30	9:54	1:24	1.40	Working in/on process system	Startup/Shutdown
12/6/02	17:54	20:48	2:54	2.90	Electrical malfunction in precipitator	Malfunction
12/17/02	2:06	3:06	1:00	1.00	Mechanical malfunction in precipitator	Malfunction
12/28/02	4:30	8:24	3:54	3.90	Lost spray tower exit temperature control	Malfunction
12/31/02	17:06	19:24	2:18	2.30	Lost spray tower exit temperature control	Malfunction
Total				**17.10**		
Third Quarter, 2002						
7/24/02	9:36	14:42	5:06	5.10	Electrical or mechanical malfunction in precipitator	Malfunction
7/25/02	6:54	11:18	4:24	4.40	Personnel working inside Process System or Pollution Control Equipment	Startup/Shutdown
8/27/02	6:18	14:12	7:54	7.90	Personnel working inside Process System or Pollution Control Equipment	Startup/Shutdown
Total				**17.40**		
Second Quarter, 2002						
4/10/02	4:00	6:24	2:24	2.40	Other known cause	Malfunction
4/10/02	9:06	15:00	5:54	5.90	Other known cause	Malfunction
4/11/02	:12	1:48	1:36	1.60	Control Equipment problems	Malfunction
4/11/02	3:24	4:30	1:06	1.10	Control Equipment problems	Malfunction
4/11/02	4:42	9:24	4:42	4.70	Control Equipment problems	Malfunction
4/11/02	9:30	11:18	1:48	1.80	Control Equipment problems	Malfunction
4/11/02	16:48	21:48	5:00	5.00	Control Equipment problems	Malfunction
4/16/02	12:42	14:24	1:42	1.70	Control Equipment problems	Malfunction
4/22/02	10:18	12:00	1:42	1.70	Control Equipment problems	Malfunction
4/26/02	3:54	8:12	4:18	4.30	Control Equipment problems	Malfunction
4/28/02	7:42	9:54	2:12	2.20	Control Equipment problems	Malfunction
5/22/02	2:30	11:12	8:42	8.70	Other known cause	Malfunction

MCC Detail of Causes of hours of average opacity above 20 percent

10/18/01	1:12	2:12	1:00	1.00	Process Problems	Malfunction
10/20/04	23:42	2:00	2:18	2.30	Process Problems	Malfunction
10/21/01	4:30	6:24	1:54	1.90	Process Problems	Malfunction
10/28/01	15:42	18:18	2:36	2.60	Process Problems	Malfunction
10/28/01	20:24	23:00	2:36	2.60	Process Problems	Malfunction
11/15/01	23:30	1:24	1:24	1.40	Process Problems	Malfunction
11/24/01	7:48	22:00	14:12	14.20	Other Known Causes	Malfunction
11/27/01	6:54	8:00	1:06	1.10	Control Equipment Problems	Malfunction
11/27/01	8:18	10:18	2:00	2.00	Control Equipment Problems	Malfunction
12/8/01	7:42	15:42	8:00	8.00	Other Known Causes	Malfunction
Total				**76.80**		
Third Quarter, 2001						
7/1/01	1:00	3:48	2:48	2.80	Control Equipment Problems	Malfunction
7/6/01	21:12	:18	3:00	3.00	Process Problems	Malfunction
7/13/01	13:12	14:54	1:42	1.70	Control Equipment Problems	Malfunction
7/18/01	0:18	2:00	1:42	1.70	Process Problems	Malfunction
7/24/01	15:36	20:06	4:30	4.50	Control Equipment Problems	Malfunction
7/25/01	1:30	3:30	2:00	2.00	Process Problems	Malfunction
8/4/01	14:36	16:06	1:30	1.50	Process Problems	Malfunction
8/7/01	16:54	18:06	1:12	1.20	Process Problems	Malfunction
8/7/01	22:48	23:54	1:06	1.10	Process Problems	Malfunction
8/8/01	10:18	11:24	1:06	1.10	Process Problems	Malfunction
8/12/01	1:30	2:30	1:00	1.00	Process Problems	Malfunction
8/16/01	7:30	10:00	2:30	2.50	Control Equipment Problems	Malfunction
8/23/01	8:24	10:06	1:42	1.70	Process Problems	Malfunction
8/27/01	14:48	22:36	7:48	7.80	Process Problems	Malfunction
8/30/01	17:48	18:54	1:06	1.10	Control Equipment Problems	Malfunction
8/31/01	12:12	13:30	1:18	1.30	Process Problems	Malfunction
9/1/01	8:54	10:00	1:06	1.10	Control Equipment Problems	Malfunction
9/14/01	18:42	20:12	1:30	1.50	Startup / Shutdown	Startup/Shutdown
9/14/01	20:18	21:42	1:24	1.40	Process Problems	Malfunction
9/15/01	0:24	1:30	1:06	1.10	Process Problems	Malfunction
9/17/01	2:42	13:12	10:30	10.50	Process Problems	Malfunction
9/18/01	9:24	10:30	1:06	1.10	Control Equipment Problems	Malfunction
9/20/01	1:18	2:24	1:06	1.10	Control Equipment Problems	Malfunction
9/22/01	11:00	12:00	1:00	1.00	Process Problems	Malfunction
9/22/01	1:18	7:24	6:06	6.10	Process Problems	Malfunction
9/23/01	17:18	19:12	1:54	1.90	Process Problems	Malfunction
9/27/01	11:24	12:30	1:06	1.10	Process Problems	Malfunction
9/27/01	20:06	21:12	1:06	1.10	Process Problems	Malfunction
9/27/01	13:30	15:06	1:36	1.60	Process Problems	Malfunction
9/27/01	20:24	21:30	1:06	1.10	Process Problems	Malfunction
9/28/01	9:00	10:06	1:06	1.10	Process Problems	Malfunction
9/29/01	19:36	21:06	1:30	1.50	Startup / Shutdown	Startup/Shutdown
Total				**70.30**		
Second Quarter, 2001						
4/2/01	3:48	5:18	1:30	1.50	Control Equipment Problems	Malfunction
4/2/01	9:00	13:24	4:24	4.40	Control Equipment Problems	Malfunction
4/2/01	4:30	6:54	2:24	2.40	Control Equipment Problems	Malfunction
4/5/01	14:54	0:00	11:18	11.30	Process Problems	Malfunction
4/8/01	0:48	3:12	2:24	2.40	Control Equipment Problems	Malfunction
4/17/01	7:36	22:24	14:48	14.80	Process Problems	Malfunction
4/21/01	11:48	16:48	5:00	5.00	Process Problems	Malfunction
4/23/01	9:30	14:12	4:42	4.70	Control Equipment Problems	Malfunction
4/23/01	14:18	15:36	1:18	1.30	Control Equipment Problems	Malfunction
4/23/01	15:48	17:54	2:06	2.10	Control Equipment Problems	Malfunction

MCC Detail of Causes of hours of average opacity above 20 percent

5/28/02	8:48	9:48	1:00	1.00	Control Equipment problems	Malfunction
6/3/02	14:36	15:42	1:06	1.10	Control Equipment problems	Malfunction
6/17/02	6:36	9:36	3:00	3.00	Other known cause	Malfunction
6/17/02	14:00	17:06	3:06	3.10	Other known cause	Malfunction
Total				**49.30**		
First Quarter, 2002						
1/11/02	16:12	17:12	1:00	1.00	Control Equipment Problems	Malfunction
1/16/02	7:00	8:00	1:00	1.00	Control Equipment Problems	Malfunction
1/17/02	13:12	5:36	16:24	16.40	Other Known Causes	Malfunction
1/18/02	7:00	8:00	1:00	1.00	Other Known Causes	Malfunction
1/27/02	1:54	3:30	1:36	1.60	Process Problems	Malfunction
1/27/02	4:54	6:36	1:42	1.70	Process Problems	Malfunction
1/27/02	16:36	18:36	2:00	2.00	Process Problems	Malfunction
1/27/02	20:18	21:48	1:30	1.50	Process Problems	Malfunction
1/28/02	22:48	:42	1:54	1.90	Control Equipment Problems	Malfunction
1/28/02	10:24	14:48	4:24	4.40	Control Equipment Problems	Malfunction
1/28/02	14:54	16:12	1:18	1.30	Control Equipment Problems	Malfunction
1/28/02	23:18	1:18	2:00	2.00	Control Equipment Problems	Malfunction
1/29/02	1:24	3:42	2:18	2.30	Control Equipment Problems	Malfunction
2/7/02	7:30	8:36	1:06	1.10	Control Equipment Problems	Malfunction
2/7/02	15:54	17:42	1:48	1.80	Control Equipment Problems	Malfunction
2/9/02	3:12	4:12	1:00	1.00	Control Equipment Problems	Malfunction
2/9/02	19:54	22:18	2:24	2.40	Control Equipment Problems	Malfunction
2/13/02	16:48	19:00	2:12	2.20	Control Equipment Problems	Malfunction
2/13/02	19:06	21:06	2:00	2.00	Control Equipment Problems	Malfunction
2/13/02	16:18	17:18	1:00	1.00	Control Equipment Problems	Malfunction
2/14/02	22:42	7:18	8:48	8.80	Control Equipment Problems	Malfunction
2/17/02	16:12	17:54	1:42	1.70	Control Equipment Problems	Malfunction
2/28/02	15:18	16:36	1:18	1.30	Control Equipment Problems	Malfunction
3/2/02	10:12	11:18	1:06	1.10	Control Equipment Problems	Malfunction
3/2/02	16:00	18:06	2:06	2.10	Control Equipment Problems	Malfunction
3/7/02	11:00	15:42	4:42	4.70	Control Equipment Problems	Malfunction
3/13/02	17:48	20:54	3:06	3.10	Control Equipment Problems	Malfunction
3/13/02	21:48	:06	2:12	2.20	Control Equipment Problems	Malfunction
3/21/02	6:30	8:06	1:36	1.60	Control Equipment Problems	Malfunction
3/21/02	23:42	0:48	1:06	1.10	Control Equipment Problems	Malfunction
3/25/02	0:00	6:48	6:42	6.70	Other Known Causes	Malfunction
3/27/02	9:36	10:54	1:18	1.30	Control Equipment Problems	Malfunction
3/27/02	16:24	18:24	2:00	2.00	Control Equipment Problems	Malfunction
Total				**87.30**		
Fourth Quarter, 2001						
10/7/01	10:42	11:42	1:00	1.00	Process Problems	Malfunction
10/7/01	15:42	16:48	1:06	1.10	Process Problems	Malfunction
10/7/01	17:36	18:36	1:00	1.00	Process Problems	Malfunction
10/11/01	17:06	0:00	6:54	6.90	Control Equipment Problems	Malfunction
10/12/01	17:06	0:00	6:54	6.90	Control Equipment Problems	Malfunction
10/13/01	5:54	7:36	1:42	1.70	Control Equipment Problems	Malfunction
10/14/01	4:54	7:30	2:36	2.60	Control Equipment Problems	Malfunction
10/15/01	2:36	3:36	1:00	1.00	Control Equipment Problems	Malfunction
10/15/01	4:42	6:42	2:00	2.00	Control Equipment Problems	Malfunction
10/15/01	12:54	14:30	1:36	1.60	Control Equipment Problems	Malfunction
10/15/01	21:24	23:12	1:48	1.80	control Equipment Problems	Malfunction
10/15/01	23:36	:48	1:12	1.20	Control Equipment Problems	Malfunction
10/16/01	:54	7:48	6:24	6.40	Control Equipment Problems	Malfunction
10/17/01	5:24	7:12	1:48	1.80	Control Equipment Problems	Malfunction
10/17/01	7:18	10:00	2:42	2.70	Control Equipment Problems	Malfunction

MCC Detail of Causes of hours of average opacity above 20 percent

4/23/01	19:42	21:12	1:30	1.50	Control Equipment Problems	Malfunction
4/23/01	21:18	22:24	1:06	1.10	Control Equipment Problems	Malfunction
5/16/01	14:24	15:30	1:06	1.10	Control Equipment Problems	Malfunction
5/18/01	13:42	18:42	5:00	5.00	Control Equipment Problems	Malfunction
5/20/01	20:52	0:00	4:18	4.30	Process Problems	Malfunction
5/25/01	14:36	16:48	2:12	2.20	Process Problems	Malfunction
5/30/01	15:48	17:06	1:18	1.90	Process Problems	Malfunction
6/7/01	8:00	10:48	2:48	2.80	Process Problems	Malfunction
6/7/01	10:54	12:00	1:06	1.10	Process Problems	Malfunction
6/7/01	13:00	14:18	1:18	1.30	Process Problems	Malfunction
6/7/01	14:48	16:18	1:30	1.50	Process Problems	Malfunction
6/7/01	18:00	19:00	1:00	1.00	Process Problems	Malfunction
6/15/01	6:00	10:48	4:48	4.80	Control Equipment Problems	Malfunction
6/15/01	12:24	15:06	2:42	2.70	Control Equipment Problems	Malfunction
6/17/01	9:12	11:00	1:48	1.80	Process Problems	Malfunction
6/18/01	10:36	11:42	1:06	1.10	Process Problems	Malfunction
6/30/01	13:30	16:30	3:00	3.00	Process Problems	Malfunction
Total				**88.10**		
First Quarter, 2001						
1/17/01	15:24	16:54	1:30	1.50	Other Known Problems	Malfunction
2/5/01	12:48	18:00	5:12	5.20	Other Known Problems	Malfunction
2/18/01	11:30	13:06	1:36	1.60	Process Problems	Malfunction
2/18/01	13:18	16:06	2:48	2.80	Control Equipment Problems	Malfunction
2/24/01	12:54	15:18	2:24	2.40	Other Known Problems	Malfunction
3/4/01	17:48	19:30	1:42	1.70	Unknown Causes	Other
3/5/01	9:18	12:24	3:06	3.10	Control Equipment Problems	Malfunction
3/10/01	2:48	7:06	4:18	4.30	Process Problems	Malfunction
3/16/01	4:24	6:42	2:18	2.30	Process Problems	Malfunction
3/26/01	19:12	21:06	1:54	1.90	Process Problems	Malfunction
3/26/01	22:00	23:54	1:54	1.90	Process Problems	Malfunction
3/27/01	0:00	6:42	6:42	6.70	Process Problems	Malfunction
Total				**35.40**		
Fourth Quarter, 2000						
10/21/00	23:24	1:36	2:12	2.20	Process Problems	Malfunction
10/26/00	18:18	19:18	1:00	1.00	Process Problems	Malfunction
10/28/00	6:12	8:24	2:12	2.20	Control Equipment Problems	Malfunction
11/28/00	2:24	4:18	1:54	1.90	Other Known Problems	Malfunction
12/18/00	21:24	23:18	1:54	1.90	Process Problems	Malfunction
12/18/00	23:24	:42	1:18	1.30	Process Problems	Malfunction
12/19/00	7:18	8:48	1:30	1.50	Process Problems	Malfunction
Total				**12.00**		
Third Quarter, 2000						
N/A						
Second Quarter, 2000						
4/7/00	5:42	12:30	6:48	6.80	Process Problems	Malfunction
4/13/00	16:12	18:36	2:24	2.40	Other Known Problems	Malfunction
4/26/00	2:36	4:06	1:30	1.50	Process Problems	Malfunction
5/17/00	17:30	19:48	2:18	2.30	Control Equipment Problems	Malfunction
5/19/00	16:12	17:24	1:12	1.20	Process Problems	Malfunction
5/25/00	16:00	17:06	1:06	1.10	Process Problems	Malfunction
Total				**15.30**		

MCC Detail of Causes of hours of average opacity above 20 percent

First Quarter, 2000						
1/25/00	4:42	10:12	5:30	5.50	Control Equipment Problems	Malfunction
2/12/00	2:48	5:00	2:12	2.20	Control Equipment Problems	Malfunction
Total				**7.70**		
4th Quarter, 12/23-31,1999						
12/28/99	14:30	16:06	1:36	1.60	Unknown Causes	Unknown or Excused Cause
Total				**1.60**		

MCC Detail of Causes of hours of average opacity above 20 percent

Attachment #5

Resume for Thomas Keeler

1979 – 1984	Field Service Engineer, Environmental Elements Corp., an original equipment manufacturer of Electrostatic Precipitators and other air and water pollution control equipment. Completed more than 50 new ESP project start-ups. Inspected and serviced 5 generations of ESP equipment in a variety of applications. Supervised construction personnel and junior field engineers. Trained plant personnel and junior field engineers.
1975 - 1979	Technician for Lehigh University Electrical and Chemical Engineering Departments, responsible for construction, testing and maintaining lab equipment and assisting professors and graduate students with projects.

EDUCATION

1975 - 1979	Lehigh University, Bethlehem, PA Major: Bachelor Science Electrical Engineering Minor: Astrophysics

ASSOCIATIONS & PUBLICATIONS

- International Society of Electrostatic Precipitation (ISESP) -member
- Institute of Electrical and Electronics Engineers (IEEE) - member
- Power - Gen Americas Conference - Round Table Panelist, ESP Maintenance Session
- III World Mining Exposition in Santiago, Chile. - presented paper "Operating and Maintenance Practices for ESPs in Industrial Processes"
- NWL Newsletter - article about "NOx Control Equipment and its effects on ESPs"
- Particulate Control Users Group Meeting - Lecturer for ESP Fundamentals Workshop & Round Table Panelist, AVC Controls Session
- 2003 Co-author and Editor of EPRI's "Electrostatic Precipitator Maintenance Guide"
- 2004 Co-author and Editor of “Operations and Maintenance Seminar - Reference Material on Electrostatic Precipitation”